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(54) **Microdispensing system for the open-jet dispensing of liquids**

(57) A microdispensing system for the open-jet dispensing of liquids, with a valve having a valve chamber (16) bounded by an impermeable elastic membrane (11) and filled with the liquid for dispensing, one or more liquid supply lines (24,26) leading to said valve chamber (16) while an outlet closed from the exterior by the membrane in the position of rest leads from said chamber to a dispensing nozzle (10). An actuator chamber (29) is disposed on the other side of the membrane and in said actuator chamber (29) there is provided an electromechanical drive (30) connected to the membrane for the purpose of briefly lifting the membrane from the outlet, and in that said actuator chamber is closed in pressure-tight relationship in such manner that it can be subjected to a pressure differing from atmospheric pressure.

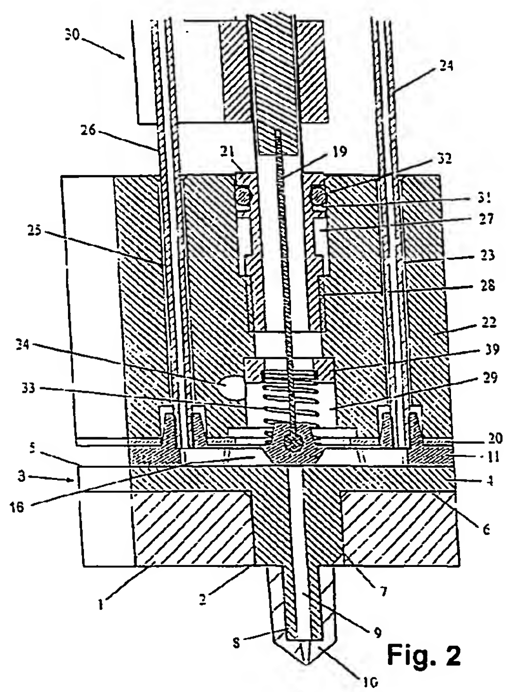

Fig. 2

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Description

[0001] The invention relates to a microdispensing system for the open-jet dispensing of liquids, with a valve having a valve chamber bounded by an impermeable elastic membrane and filled with the liquid for dispensing, a liquid supply line leading to said valve chamber while an outlet closed from the exterior by the membrane in the position of rest leads from said chamber to a dispensing nozzle.

[0002] For the purpose of this description, the term "microdispensing" is used to denote the dispensing cf volumes of liquid in the region of 10 microliter and less. The term "open-jet dispensing" denotes dispensing in which the dispensing nozzle and the target are separated by an air gap in order to avoid contamination.

[0003] Open-jet dispensing systems consist of a dispensing nozzle, a liquid supply line to the dispensing nozzle, and a dispensing drive.

[0004] Different operating principles are known for the dispensing drive in microdispensing systems and piezo-actors, bubble-jet actors, electrostatic, pneumatic and magnetostrictive drives are in practical use. The most important areas of use of these drives are inkjet printing and micropipetting.

[0005] For the dispensing of biological liquids and suspended cells it is very important that no or minimal shearing forces, pressure and temperature influences should occur. Consequently, however, the known drives can be used only to a limited degree. In particular, the heating of the liquid by the waste heat of the electromechanical drives of known systems has an adverse effect on the stability of protein and enzyme solutions during the dispensing thereof.

[0006] Before the actual dispensing operation most microdispensing systems have to be vented and initialized by dispensing runs. After dispensing, each microdispensing system had to be emptied, flushed and cleaned. In both cases it is extraordinarily important to use the usually expensive liquids sparingly. The known microdispensing systems can be initialized, emptied or flushed only by means of a large number of dispensing runs with repeated actuation of the drive and after dispensing completely discard the excess liquid so that recovery is impossible.

[0007] It is precisely cleaning which constitutes a considerable practical problem in microdispensing systems and this applies particularly to the dispensing nozzle. Depending on the type of construction thereof, it cannot be interchanged and can be cleaned only with difficulty, if at all, in the event of contamination or any clogging.

[0008] In addition, most known dispensing systems are not made completely from inert materials. In known electromechanical dispensing systems the drive is often subjected to liquid for dispensing flowing around it. Apart from the above-mentioned heating, this can also lead to contamination of the liquid and incorrect operation of the drive due to soiling.

[0009] Another disadvantage of known open-jet dispensing systems is that the quantity dispensed per run is predetermined by the construction and is influenced by the viscosity and surface tension of the liquid for dispensing.

[0010] The object of the invention is to provide a rugged and inert dispensing system by means of which microvolumes of liquids of the most diverse physico-chemical properties can be delivered to the target without contamination with minimum loss and with a preselectable dispensed volume without any substantial influence from shearing forces, increased temperatures and pressure waves.

[0011] According to the invention, to this end, an actuator chamber is disposed on the other side of the valve membrane and in said actuator chamber there is provided an electromechanical drive connected to the membrane for the purpose of briefly lifting the membrane from the outlet, and said actuator chamber is closed in pressure-tight relationship in such manner that it can be subjected to a pressure differing from atmospheric pressure. The valve has two supplies which allow venting, flushing and recovery of the liquid for dispensing without actuating the dispensing drive. The dispensing nozzle is made from an inert and hydrophobic elastomer, and this prevents clogging and facilitates cleaning.

[0012] A preferred embodiment of a microdispensing system according to the invention comprises a valve, at least one liquid supply line, an outlet, a dispensing nozzle, an actuator chamber, and an electromechanical drive. The valve has a chamber that is formed at least in part from a liquid-impermeable elastic membrane that can be stretched from a resting position to a stretched position. The valve chamber is filled with the liquid to be dispensed. At least one liquid supply line is in liquid communication with the valve chamber. This at least one supply line is configured and dimensioned for supplying liquid to the valve chamber. The outlet is open to liquid communication with the valve chamber when the elastic membrane is in the stretched position and closed to liquid communication with the valve chamber when the elastic membrane is in the resting position. The outlet is configured and dimensioned so that when the elastic membrane is in the stretched position, liquid from the valve chamber enters the outlet. The dispensing nozzle is configured and dimensioned to be in liquid communication with the outlet and to open-jet dispense liquid. The dispensing nozzle is constructed so that when liquid flows from the outlet into the dispensing nozzle, it is open-jet dispensed from the dispensing nozzle. The actuator chamber located adjacent the elastic membrane on the side of the membrane opposite the valve chamber. The actuator chamber is configured and dimensioned to be pressure-tight and to retain a pressure differing from atmospheric pressure. The electromechanical drive is located within the actuator chamber and is connected to the membrane. The electromechanical

drive is constructed so that when actuated, it stretches the membrane from the resting position to the stretched position, thereby allowing liquid from the valve chamber to enter the outlet and to be open-jet dispensed through the dispensing nozzle.

[0013] Further details and preferred features of the invention will be apparent from the following description in conjunction with the accompanying drawings which illustrate preferred exemplified embodiments and in which:

- Fig 1 is a perspective view of a single microdispensing device.
- Fig 2 is a section on the plane defined by the line A-A in Fig 1.
- Fig 3 is a perspective view of a unit with eight identical microdispensing devices disposed in line.
- Fig 4 is a system of four units of the kind shown in Fig 3 disposed side by side.
- Fig 5 is a perspective view of a membrane element from above (5a), from below (5b) and in section (5c) on the line B-B.
- Fig 6 is a perspective view of the dispensing nozzle from above (6a), from below (6b) and in section (6c) on the line C-C.

[0014] As will be seen from Figs 1 and 2, a rectangular base plate 1 has a central bore 2. A dispensing nozzle element 3 has a rectangular top part 4 with a flat top surface 5 and a likewise flat bottom surface 6, and a cylindrical bottom part 7 with an extension 8 constructed in the form of a capillary tube. A bore 9 extending from the top surface 5 through the entire element leads into the bottom end of the extension 8. The extension 8 is provided with an interchangeable elastic dispensing nozzle 10 with a capillary passage.

[0015] The dispensing nozzle element 3 rests with its bottom surface 6 on the base plate, and the bottom part 7 with the extension 8 extends through the bore 2.

[0016] As shown in Fig 6, the dispensing nozzle 10 consists of a cylindrical part 40 and a conical part 41, both of which are provided with a central bore 42,43. The central bore 42 in the cylindrical part has a diameter such that the dispensing nozzle can be pushed on to the capillary tube 8. In the conical part, the central bore 43 tapers from a diameter corresponding to the bore 9.

[0017] The dispensing nozzle is made from an inert hydrophobic elastomer. The elastic properties prevent the nozzle from clogging and facilitate cleaning without having an adverse effect on the open-jet dispensing of the small volumes of liquid. Also, the elastic dispensing nozzle is much less sensitive to mechanical damage than prior art dispensing nozzles made of glass or other hard materials.

[0018] Advantageously, for production and handling reasons, a plurality of or all the dispensing nozzles for a dispensing line or a dispensing array are connected to form a unit.

[0019] As shown in detail in Fig 5, a membrane element 11 is substantially disc-shaped and has substantially identical dimensions to the dispensing nozzle element 3. In its bottom surface, the membrane element has a concentric annular recess 12 and two ducts 13 disposed opposite one another and connecting the annular recess to off-center bores 14, which further outwards pass through the membrane element 11 in parallel relationship to the axis. The center surrounded by the recess 12 is formed by a truncated cone 15. The membrane element 11 rests by its bottom surface on the top surface of the dispensing nozzle element. In this position, the annular recess 12 and the ducts 13 form a chamber 16 around the truncated cone 15, the flat bottom surface of which covers the bore 9. The chamber 16 is designated as valve chamber.

[0020] The top surface of the membrane element has collar-shaped sealing lips 17 surrounding the bores 14 and a central thickening 18 which is directed axially upwards and into which there is cast an elongate cylindrical axially disposed extension 19 of metal. A sealing disc 20 made from an elastomer adjoins the membrane element 11 on the side of the top surface thereof. The sealing disc has a rectangular shape of substantially the same size as the base plate 1 and is provided with bores to receive the sealing lips 17 and a central bore corresponding approximately to the outside diameter of the annular recess in the underside of the membrane element.

[0021] A block 22 adjoining the sealing disc 20 serves to accommodate the supply lines and the actuating device for the valve. The block has two bores 23,25 which are concentric with the off-center bores 14 of the membrane element 11 and the corresponding bores of the sealing disc 20 and through which extend two supply capillaries 24,26 both of which lead by their bottom ends into the off-center bores 14 surrounded by the sealing lips 17 and are thus in communication with the chamber 16.

[0022] In their bottom part, the off-center bores 23,25 in the block 22 have a widened diameter to receive the sealing lips 17. The remaining part of the bores is adapted to the capillaries 24,26.

[0023] A central bore 27 in the block 22 has a narrower middle zone provided with a screw thread 28 and zones which widen out upwardly and downwardly. In the downward direction a two-stage widening is provided, the bottom diameter of which again corresponds to the outside diameter of the annular recess in the membrane element. These widened diameters form a chamber 29 above the membrane element 11 around the thickening 18, said chamber 29 being situated on the drive side of the membrane element and hence being designated an actuator chamber. The actuator chamber is separated from the valve chamber 16 by the thin zone of the membrane element in the region of the recess 12, which zone thus forms a membrane.

[0024] The substantially tubular housing 21 of a drive

element 30 for the valve is inserted in the central bore 27. A known solenoid drive is used as the drive element. The housing 21 has in its middle zone a thickening with a suitable external screw thread for screwing it into the screw thread 28 of the bore. A peripheral groove 31 to receive an O-ring 32 is also provided in the thickened zone and seals off the bore 27 and hence the chamber 29 from the exterior.

[0025] A cylindrical disc 39 is pressed into the bottom part of the central bore 27. A spiral spring 33 extends from the underside of the disc 39 as far as the top surface of the membrane element. In the installed condition the spring 33 is stressed so that it presses the truncated cone 15 of the membrane 11 on to the top surface 5 of the dispensing nozzle element 3.

[0026] From the cutside of the block 22 a bore 34 leads to the chamber 29.

[0027] During operation, a liquid substance for dispensing flows through the capillary 26 into the chamber 16 and out of the chamber via the capillary 24. The chamber 16 is thus permanently filled with the liquid substance. To dispense a specific volume through the dispensing nozzle 10, the membrane is briefly pulled upwards by means of its extension 19 through the agency of an electrical pulse to the solenoid drive, and the bore 9 in the dispensing nozzle element 3 is thus released. Substance can flow out during this opening of the bore 9. When the solenoid drive again releases the membrane, it drops as a result of the spring and its own elasticity and closes the bore. The volume that flows out depends linearly on the duration of the opening of the bore. By varying the duration of the electrical pulse it is possible to change the valve opening time and set the dispensed quantity to a predetermined value.

[0028] The membrane movement takes place extraordinarily quickly, so that the opening and closing processes are very short. This leads to very high precision during dispensing.

[0029] Through the bore 34 in the block 22 to the chamber 29 above the membrane 11 it is possible to subject this chamber to a working pressure adapted to the pressure in the chamber 16. This enables the relative pressures between the chamber 29 and chamber 16 and their difference from the external atmospheric pressure to be freely selected. For example, in the case of an excess pressure of 1 bar in the chambers 16,29 the membrane 11 is relieved of load so that extremely short opening and closing times are obtained together with high dispensing precision for small dispensed quantities.

[0030] The double supply to the chamber 16 enables the valve to be vented and flushed without actuating the drive. The reagents fed via capillary 26 can also be recovered via the capillary 24 on emptying the valve.

[0031] The local separation of the electromechanical parts 19,21,30,33 from the fluidics consisting of the capillaries 24,26 and the chamber 16 prevents the liquid from being heated by the waste heat of the electromechanical drive 30, any contamination of the liquid, and any corrosion of the electromechanical parts by corrosive liquids.

[0032] As shown in Fig 3, a plurality of microdispensing valves, eight in the present case, can be disposed in series. For this purpose the base plate 35, the dispensing nozzle element 36 and the block 37 are lengthened accordingly and provided with the corresponding number of bores. The membrane elements can be disposed individually therebetween. Alternatively, a multiple membrane element can be provided. The supply bore 38 for the working pressure is fed to all the chambers through the entire block. The distances between the bores in the base plate and the block correspond to the module used for conventional microtiter plates.

[0033] Fig 4 shows how a plurality of the elements in series can be combined side by side to form a flat system of 32 dispensing units. The individual series elements are in this case each offset 2.25 millimeter in the longitudinal direction. The module dimension is 9 millimeter. With a system of this kind it is possible to fill high-integration plates with one pass.

List of reference numbers

[0034]

1	base plate
2	bore
3	dispensing nozzle element
4	top part of nozzle element 3
5	flat top surface of nozzle element 3
6	flat bottom surface of nozzle element 3
7	7 cylindrical bottom part 7 of nozzle element 3
8	extension / capillary tube
9	bore
10	interchangeable elastic dispensing nozzle
11	membrane element
12	concentric annular recess 12 of membrane element 11
13	duct
14	bore
15	truncated cone
16	valve chamber
17	sealing lip
18	central thickening
19	metallic extension
20	sealing disc
21	tubular housing
22	block
23	bore
24	supply capillary
25	bore
26	supply capillary
27	bore
28	screw thread
29	chamber

30 drive element
31 peripheral groove
32 O-ring
33 spiral spring
34 bore
35 base plate
36 dispensing nozzle element
37 block
38 supply bore
39 cylindrical disc
40 cylindrical part of nozzle 10
41 conical part of nozzle 10
42 bore 42 of part 40
43 bore of part 41

[0035] It should be understood, however, that the present invention herein illustrated and described is intended to be representative only, as many changes may be made therein without departing with the clear teachings of the invention. Accordingly, reference should be made to the following claims in determining the full scope of the invention, as it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope and fair meaning of the appended claims.

Claims

1. A microdispensing system for the open-jet dispensing of liquids, with a valve having a valve chamber (16) bounded by an impermeable elastic membrane (11) and filled with the liquid for dispensing, one or more liquid supply lines (24,26) leading to said valve chamber (16) while an outlet closed from the exterior by the membrane in the position of rest leads from said chamber to a dispensing nozzle (10), characterized in that an actuator chamber (29) is disposed on the other side of the membrane and in said actuator chamber (29) there is provided an electromechanical drive (30) connected to the membrane for the purpose of briefly lifting the membrane from the outlet, and in that said actuator chamber is closed in pressure-tight relationship in such manner that it can be subjected to a pressure differing from atmospheric pressure.

2. A microdispensing system according to claim 1, characterized by two supplies (24,26) to the valve chamber, which allow venting, flushing and recovery of the liquid for dispensing, without the drive being actuated.

3. A microdispensing system according to claim 1 or 2, characterized in that the dispensing nozzle 10 is interchangeable and consists of an inert hydrophobic elastomer.

4. A dispensing nozzle for use in a microdispensing system according to any one of claims 1 to 3, characterized in that it consists of an inert hydrophobic elastomer and is interchangeable.

5. A dispensing nozzle according to claim 4, characterized in that together with a plurality of identical dispensing nozzles it forms an array.

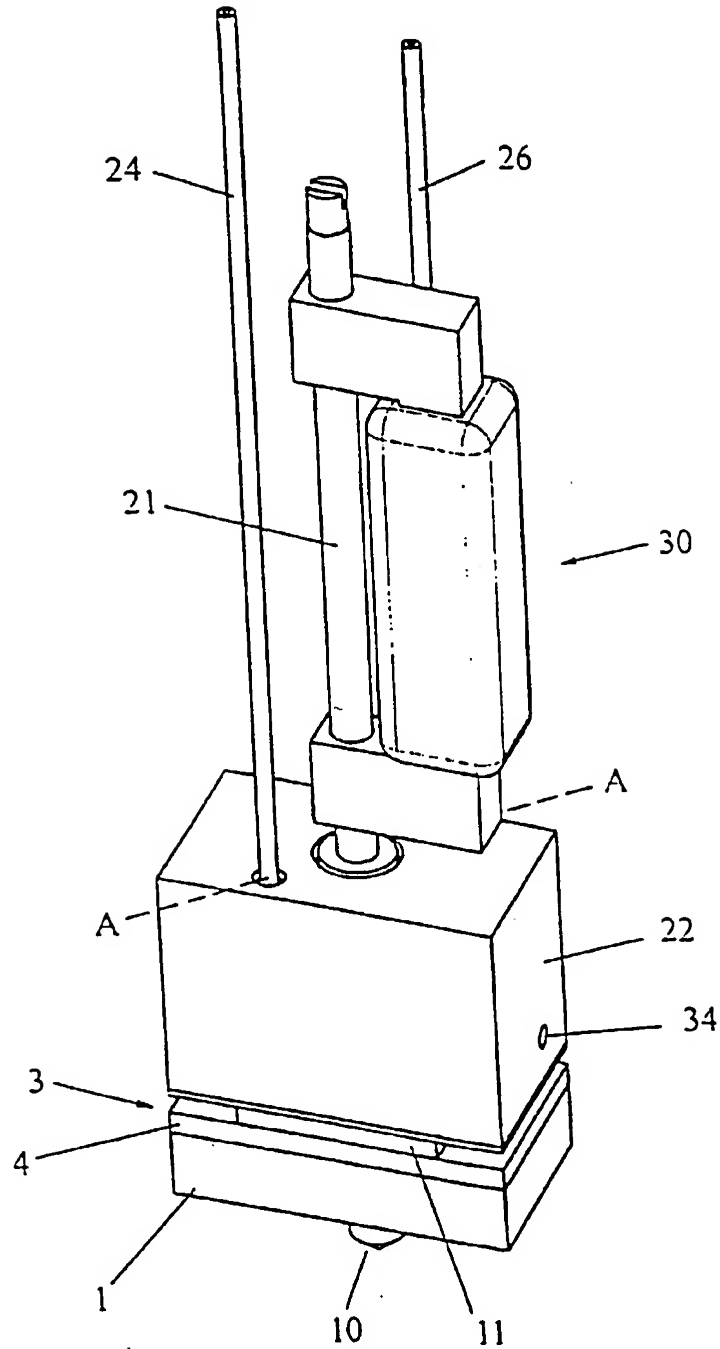

Fig. 1

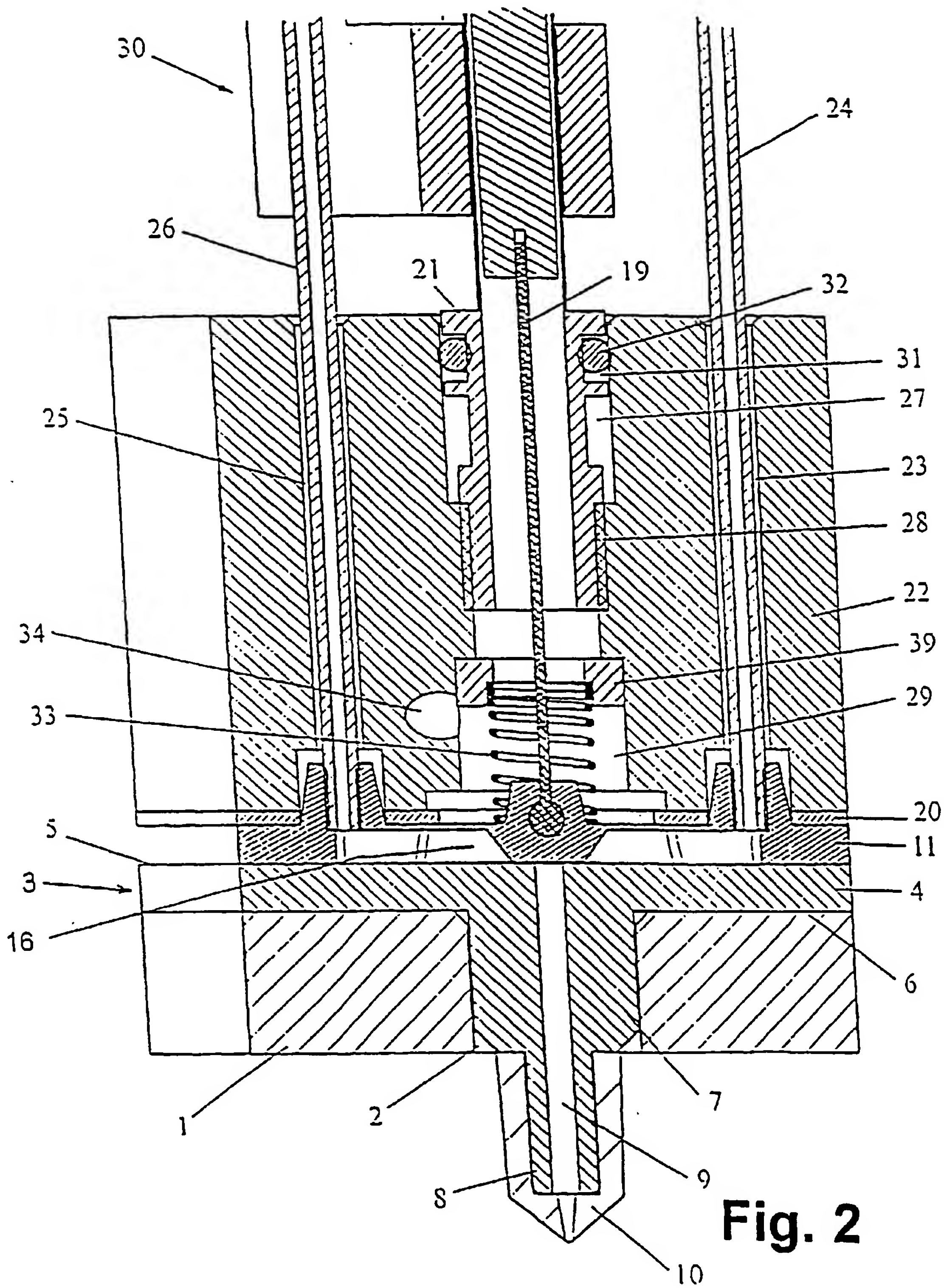

Fig. 2

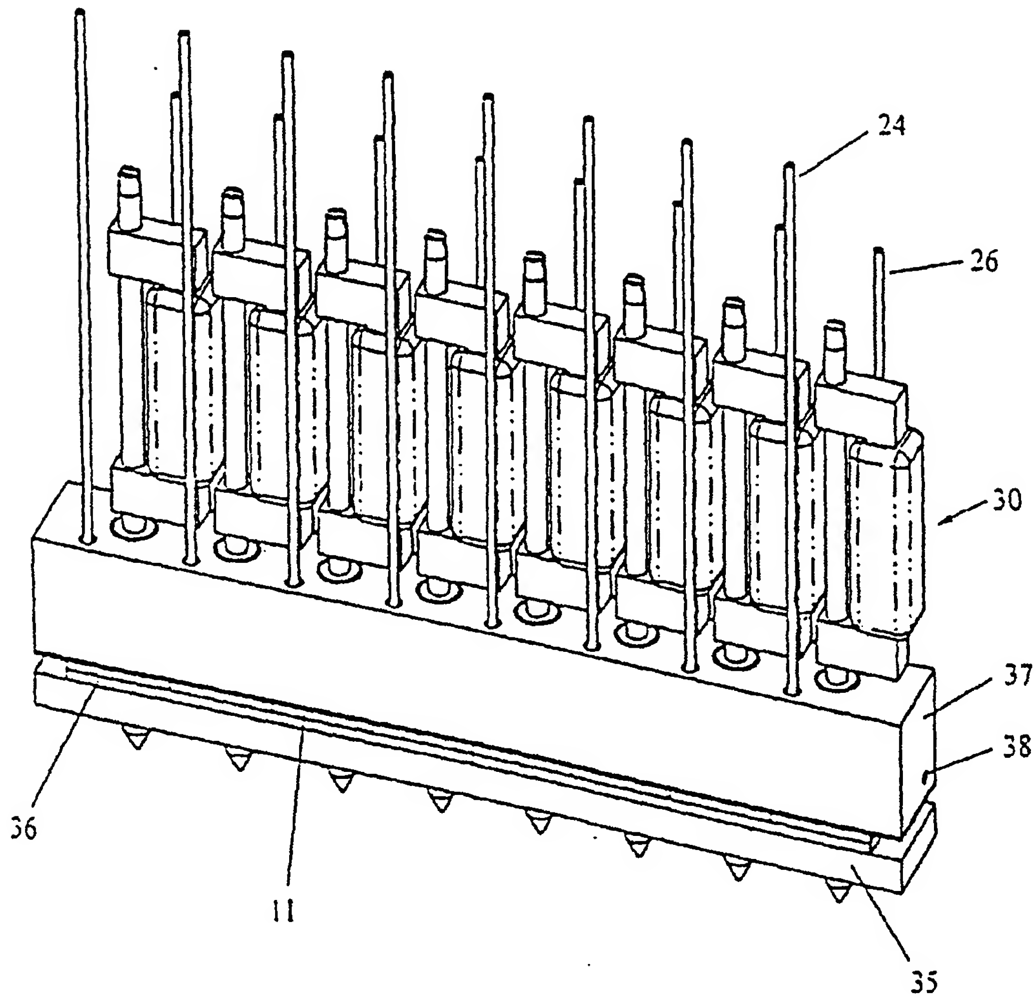

Fig. 3

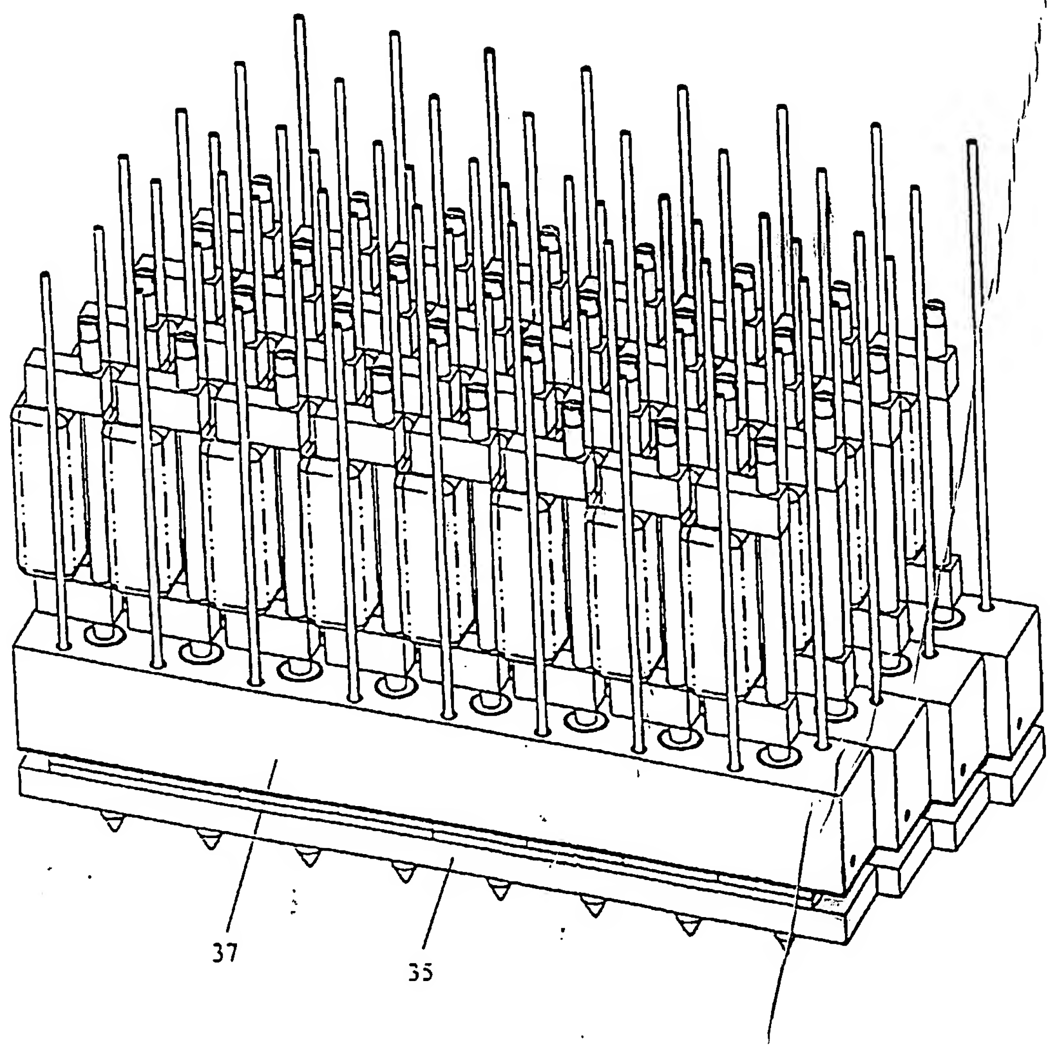

Fig. 4

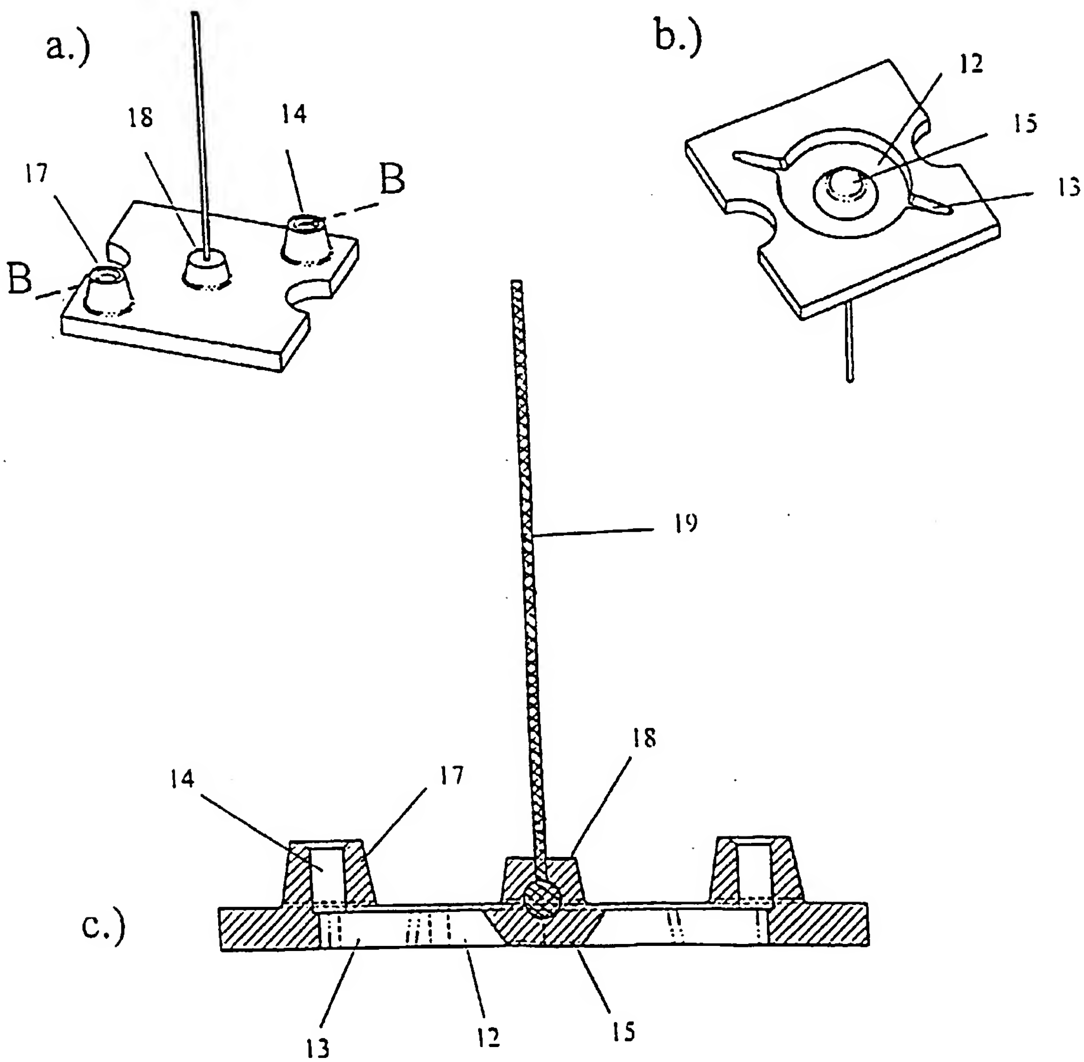

Fig. 5

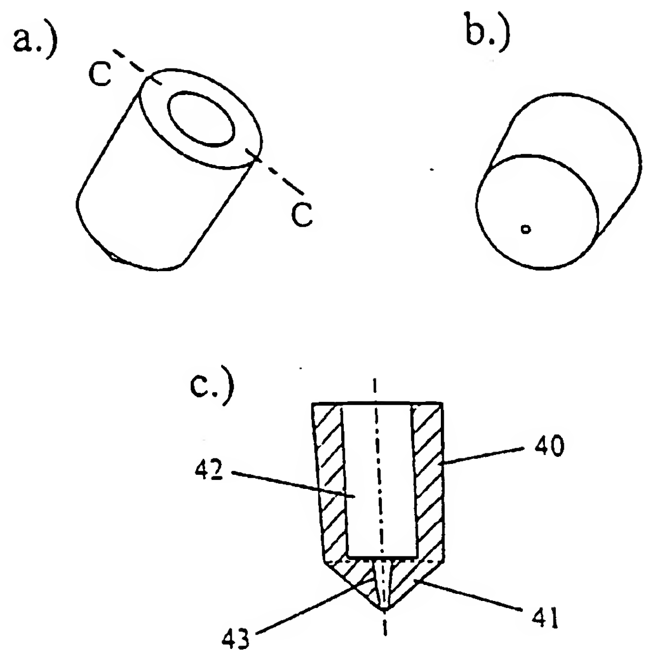

Fig. 6